# Refrigerator as Model of How Water Manages Solar and Anthropogenic Heats and Controls Global Warming

Michel Vert

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**Michel Vert**[1,*]

1 Institute for Biomolecules Max Mousseron, UMR CNRS 5247, Department of Artificial Biopolymers, University of Montpellier-CNRS-ENSCM, Faculty of Pharmacy, 15 Avenue Charles Flahault, BP 14491, 34093 Montpellier Cedex 5, France; michel.vert@umontpellier.fr

* Correspondence: michel.vert@umontpellier.fr; Tel.: +33(0) 612 522811

ABSTRACT: The role of anthropogenic carbon dioxide ($CO_2$) in global warming and climate change is confusing. Experts in greenhouse effects predict that changes in ocean level and atmospheric temperature, which are still presently very small, will increase considerably in distant future. On the other hand, the loss of ices is already dramatic. Greenhouse gases, in particular $CO_2$, are said responsible for the global warming but they do not explain the dominance of ice loss relative to atmosphere and ocean temperature increases. On the basis of chemical and physical fundamentals, it was previously shown that the anthropogenic heat released between 1994 and 2017 has provided enough heat to cause the melting of a large part of the global ice lost during the same long period. To go farther, the present contribution compares the management of solar heat on Earth with the thermodynamic cycle used to control the temperature inside refrigerators. The discussion shows that solar heat and anthropogenic heat are managed similarly using water as refrigerant and that the equilibria between water physical states (ice, liquid and vapor) are buffering phenomena relative to climate changes. It is also shown that the combustion of fossil hydrocarbons is releasing a huge amount of water that has been stored for millions of years as hydrogen in hydrocarbon fossil sources of energy. However, this extra water remains minor compared with the water issued from global ice imbalance. The last part proposes to use heat-cycle assessment from cradle to grave as means to compare different energy sources in the search for ways to minimize anthropogenic heat release and possibly global warming. Water electrolysis could then be a climate- and environment-friendly source of renewable hydrogen-based energy provided the electricity necessary to generate hydrogen can be produced on a large scale with better heat-cycle and life-cycle than traditional sources.

Keywords: climate changes; anthropogenic heat release; AHR; water-interphase equilibria; ice loss; heat cycle assessment, global warming

## INTRODUCTION

So far, the predictions of climate changes are based on hypotheses and calculations of evolutions for the far future as reported in successive UN Intergovernmental Panel on Climate Change (IPCC) reports [1]. The conclusions result from an international consensus that predicts climate changes and dramatic atmosphere temperature and ocean level rises in several decades from now. The consensus is almost universal although controversies exist that are frequently limited to non-peer-reviewed open access or magazine outlets [2]. Until recently, the sun-dependent global climate was related to balanced inputs and outputs of electromagnetic infrared radiations and on effects of greenhouse gas, especially anthropogenic $CO_2$ [1, 3-5]. Today, a small part of the solar energy due to aerosols is now proposed absorbed by environmental elements (oceans, ice, land, etc.) where it causes heating [6-7]. This retained solar energy comes in addition to the excess of greenhouse-type heating due to anthropogenic $CO_2$. The residual heat that is not returned to space has to be globally balanced otherwise the Earth would grow warmer and warmer. Water cycle has been recognized for years as an important factor in climate control through evaporation-condensation phenomena [8-9]. Recently, NASA recalled the role of water cycle and proposed a program intended at monitoring polar ice evolution using satellites [10]. The occurrence of dramatic ice loss has been clearly observed, especially over the recent years, at the levels of ice caps, sea ice, glaciers, and permafrost [11-12]. However, ice loss is generally considered as a source of ocean rise and not specifically as a global warming regulator.

The possible contribution of anthropogenic heat release (AHR) to global warming has been neglected until recently. The context and the history are well introduced in a recent publication [13] in which the authors proposed an algorithm to evaluate global AHR. This approach consists in calculations based on heat energy estimates derived from urban zones. Although there were some limitations, the algorithm provided multi-scale anthropogenic heat information said reliable and useable for further research on regional or global climate changes and on urban ecosystems despite problems raised by difficulties to establish ratios for converting energy consumption to anthropogenic heat.

We recently proposed a different approach [14] based on fundamentals of chemistry and physics and on annual global energy consumptions derived from various sources (fossil ones, biomass, nuclear electricity, etc.) found converted in oil-equivalent in the Web [15-16]. In the absence of relative yields in work and heat for the various consumed energies, AHR was limited to 60% of the global energy consumption. It was shown that anthropogenic heat released between 1994 and 2017 had provided enough heat to cause the melting of a large part of the ice lost during the same long period. The comparison was used to speculate about evolution of the global climate in the absence of possibility to demonstrate climate-related phenomena experimentally because of the size and the complexity of the planet.

For billions of years, solar radiations have been heating the global environment without dramatic heat accumulation. The energies consumed by humans that generates anthropogenic heat release (AHR) now considered as no longer negligible, must be managed similarly and simultaneously to keep Earth's environment and climate under relative control. Indeed, the Earth can be schematically considered as a huge globe whose ground, solid matters, surface water and atmosphere are heated through excitation of molecules by interaction with solar electromagnetic radiations. Without compensation to keep the temperature compatible, the accumulated heat would have precluded the appearance of life on Earth. If the greenhouse effect well accounts for the 18°C excess of Earth’s temperature relative to what it would be in the absence of atmosphere, it cannot explain the absence of accumulation of solar heat on Earth if part of it is retained. So far, rejection of some infrared electromagnetic waves to space is the mechanism largely adopted in the world [2].

A few thousand years ago, humans began to use biomass as sources of heat and light energies. The resulting AHR remained negligible compared with solar input until about 150 years ago when humans began to exploit fossil sources of energy, and more recently nuclear plants and renewable resources for the production of electricity, all to satisfy work, heat and comfort they needed. The side effect was the appearance of much greater amounts of anthropogenic heat releases that are now considered as able to affect the climate [13-14]. The corresponding heat accumulated on Earth had to be compensated otherwise the planet would have grown warmer and warmer over the years. With this regard, Earth can be compared with a mammalian body whose metabolism generates heat in a closed space. This space has to be cooled down to keep its temperature constant. Based on this analogy, this work aims to compare Earth's water with the refrigerant that controls the temperature inside a refrigerator; another case where inner heat has to be eliminated.

## THE REFRIGERATOR

From a thermodynamic viewpoint, a refrigerator is based on a simple physical rule: “when two substances are in contact, the hot one supplies heat to the cold one up to equilibrium”. In a refrigerator, the transfer of heat proceeds by change of the physical state of a volatile fluid: the refrigerant. Heat is absorbed locally by the evaporation of the fluid, transported by the gas phase, and released from this gas by condensation in a different place. To some extent, this is how the temperature of humans and mammalians is fixed. An amount of warm liquid water present in the body is expulsed through the skin by perspiration. The sweat cools the surface and the interior of the body by evaporation in the atmosphere until perspiration is no longer necessary. The transfer of heat from a hot medium to a cold one is spontaneous and rather slow as it is the case for the human body. In contrast, heat exchanges from a cold medium to a hot one cannot be spontaneous. Some energy must be supplied. It is the role of the compressor present in air-conditioning machines and refrigerators. For humans, there is no compressor and the pressure in tissues is the sole driving force that pushes water outside prior to its evaporation to keep the inner temperature constant. A schematic representation of a refrigerator is shown in Figure 1. The main stages of the cooling process are the following:

*Evaporation*

From 1 to 2 in Figure 1, the refrigerant enters the inner evaporator as a liquid. Going through this multi-tube device, the liquid absorbs part of the heat present in the closed space, including the foods which are in it. As a result, the liquid is turned to gas at the outlet of the evaporator while the temperature inside the closed space decreases slightly.

*Compression*

From point 2 to point 3, the gas is pressurized in the compressor where it is super-heated by compression to allow spontaneous transfer from hot to cold in the multi-tube condenser located outside.

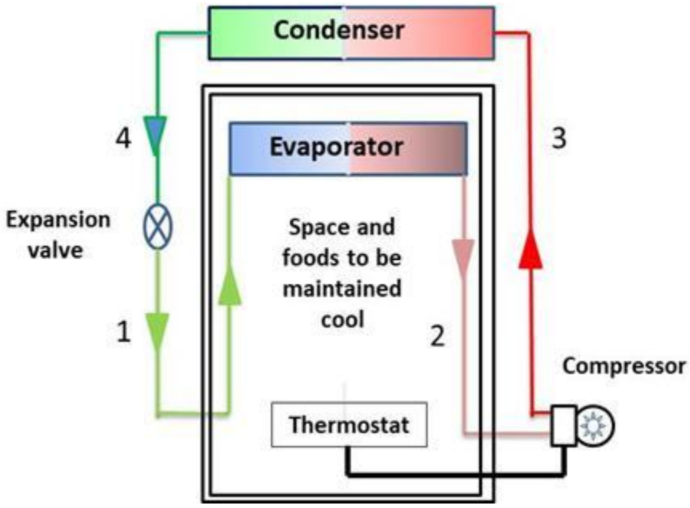


Figure 1: Schematic representation of a Vapor Compression-Refrigeration cycle.

*Condensation*

From point 3 to point 4, the hot pressurized gas enters the condenser. The initial part of the cooling process in the condenser is contact with the outer cold air that decreases the temperature of the gas before turning it back to liquid. This step is where the heat absorbed by the refrigerant at the evaporation stage is vented out to atmosphere.

*Expansion of the subcooled and highly pressurized refrigerant*

From point 4 to point 1, the high-pressure subcooled liquid passes through the expansion device which reduces its pressure and controls the flow into the evaporator. The cycle is repeated until the temperature in the refrigerator reaches the temperature set at the thermostat.

## APPLICATION TO SOLAR ENERGY MANAGING ON EARTH

If Earth is an opened system in terms of electromagnetic radiations, it is a close system in terms of heat exchanges between solids, liquids and gas she is made of. Accordingly, the ground surface, the water (oceans, seas, ponds and rivers), the atmosphere bound to the globe by gravity, and the ice (polar caps, glaciers and floating ices) have been heated by the Sun for billions of years in the past without heat accumulation. These environmental elements can be compared to the foods inside the refrigerator where the temperature is controlled. However, there are differences. The compressor present in Figure 1 to allow and speed up the thermal exchanges from cold inside to hot outside is not necessary and is replaced by chaotic turbulences in atmosphere (winds, streams, tornadoes, hurricanes) and oceans (hot and cold streams) to dispatch heat within the cold atmosphere. The condenser is replaced by the cold zone of the atmosphere where vapor condensates to form clouds. The refrigerant present in the cooling circuit of the refrigerator is replaced by water, and the heat released during cloud formation is eliminated from the high atmosphere by radiation to the space. The whole process is schematized in Figure 2.

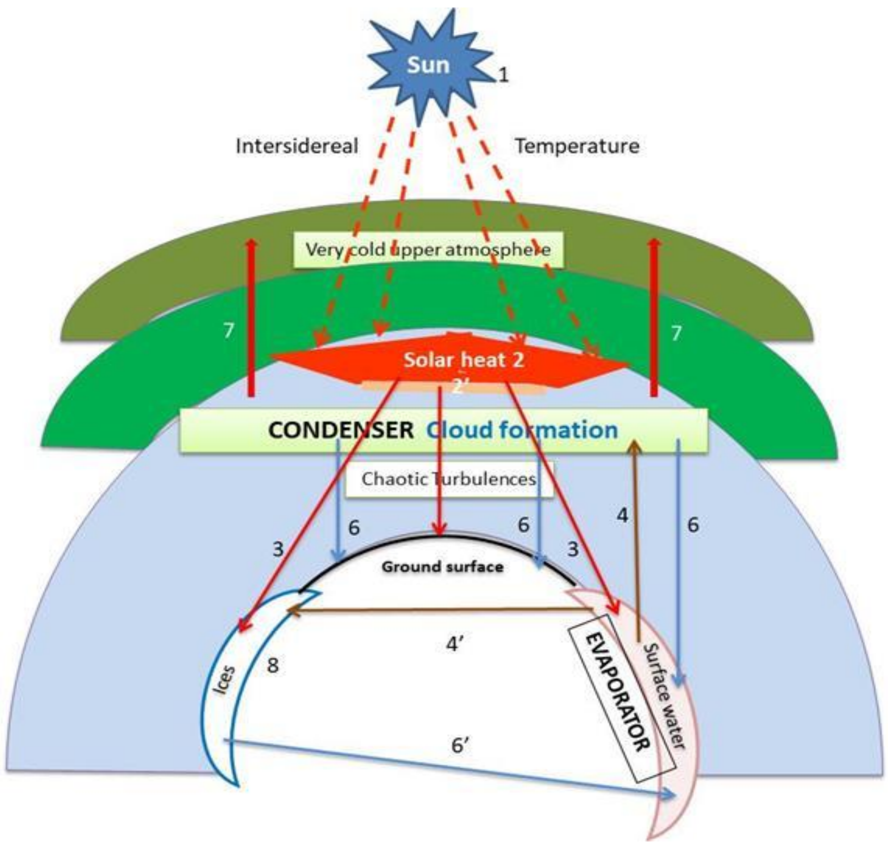


Figure 2: Schematic representation of the machinery that manages residual solar heat energy through water phase exchanges.

In this scheme, the Sun (1) heats the whole environment as everybody feels it under sunshine (2 and 3). Greenhouse effect-dependent energy (2') comes in addition. The turbulences dispatch these heats within the multilayered atmosphere in contact with the very cold intersidereal medium on one side, and with ground, ice and surface water through the low atmosphere on the other side. The supply of geothermal heat is generally considered as negligible. The temperatures of the ground surface and of the ocean tend to increase but part of the responsible heat is slowly balanced by the melting of ices (4' and 6'), at least globally. The other part is balanced by the process of evaporation (evaporator) that cools the water and transfers the corresponding heat to the atmosphere as warm vapor (4). The air enriched in warm vapor being less dense than dry air rises up to a zone cold enough to condense the vapor as dispersed droplets forming clouds while the heat stored in the vapor is released to the upper cold atmosphere which irradiates it away (7). Once clouds are formed, rains (6) close the cycle and return water to the surface. Such cycle is not uniform. In reality, the Sun does not heat continuously. Earth inclination and rotation lead to cyclic heating and cooling according to day and night, summer and winter, North and South hemispheres, and the Sun long cycles as well. The process of melting and reforming of ice is thus cyclic with ups and downs as in a refrigerator. If all the ice disappear inside the refrigerator, the inner temperature starts rising unless the thermostat restarts the cycle to reform ice. In the case of Earth, when all the ice will have melted, temperature balancing will be handled by the dominance of the right shift of evaporation ↔ vapor ↔ condensation interphases equilibria, i.e. up to the formation of a thick cover of clouds that, finally, will block, like durst particles are said doing, the input of solar heat leading to regeneration of ice on Earth [15].

## THE EVOLUTION AFTER THE APPEARANCE OF ANTHROPOGENIC HEAT

The climate controlling process described in the previous section worked for billions of years to manage Sun and biomass-related heat by cyclic ice melt and reformation and by radiation to space. The exploitation of fossil oil-derived energy started bringing in extra heat in the middle of the $19^{th}$ century. Then, natural gas and more recently electricity came that both inserted extra heat to be balanced. The new situation is schematically represented in Figure 3.

The comparison between Figures 2 and 3 does not reveal great change relative to the whole thermal machinery. The solar energy still heats the Earth dominantly (2) but the resulting greenhouse part (2') is now complemented by a contribution of anthropogenic greenhouse gas (2"). On the other hand, the released anthropogenic heat from fossil sources and electricity complements the solar heat supply and thus contributes as a surplus of atmosphere, surface water, and ice heating. This surplus is managed by ice melt and water evaporation as in the case of Figure 2 and leads to surpluses of ice melt (8) and of water evaporation (4).

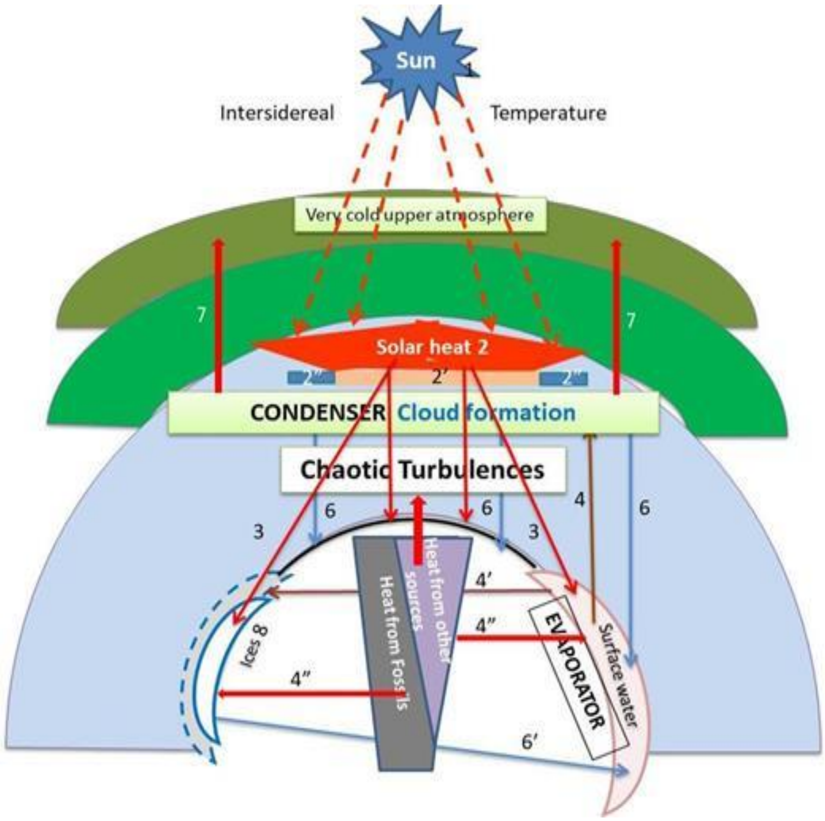


Figure 3: Schematic representation of the management of increasing amount of anthropogenic heat through evaporation-condensation-evaporation balanced by ices melt.

The greater amount of warmed vapor rises to the cold zone of the atmosphere where it releases the stored heat and, finally, forms more clouds than when the Sun was the only source of heating. The cloud water goes back to surface water as rains (6). Handling more thermal energy makes local chaotic turbulences (hurricane, tornado, rain, flooding, etc...) more important and more frequent. The Sun activity is unchanged with daily, annual and longer cyclic ups and downs modulations. In contrast, AHR occurs almost continuously over days and nights, this in acceleration over the years so far.

## WHAT ABOUT THE WATER GENERATED FROM FOSSIL HYDROCARBONS?

For a majority of scientists who try to understand and account for climate changes, the anthropogenic heat generated by humans and human's activities is negligible relative to the effects of greenhouse gas, especially those related to the $CO_2$ issued from fossil sources of energy. Among these sources, coal, which is mainly composed of carbon, generates hot carbon mono and dioxide on burning but no water, at least directly. In contrast, all the hydrocarbons (oil, natural gas, and biomass) generate hot $CO_2$ from the carbon content and hot water vapor from the hydrogen one. We already discussed the contribution of this anthropogenic hot vapor as part of AHR [14]. However, once the heat is transferred to the environment, the cooled water previously chemically stored in hydrocarbons constitutes a surplus of water on Earth.

Quantifying the amount of such extra water is as difficult as quantifying heat releases. Nevertheless, data on the overall production of fossil oil and natural gas are available and provide means to estimate the extra water produced by the combustion of hydrocarbons of fossil origin. Between 1870 and 2018, about 180 Gt of oil and 30 Toe of natural gas have been extracted [16-19], i.e. about 210 Gt of hydrocarbons. To compensate the complex composition of oil and natural gas, one can assume these fossil hydrocarbons, including methane ($CH_4$), are composed of alkanes only, the general chemical formula of which is $C_nH_{2n+2}$ reasonably simplified to $nCH_2$. Accordingly, 210 Gt of oil or oil equivalent contain c.a. 180 Gt of carbon and 30 Gt of hydrogen. From the general equation $CH_2 + 3\ O_2 \rightarrow CO_2 + H_2O$ + heat where 14 g of hydrocarbon (12 + 2) generates 44 g of $CO_2$ (12 + 32) and 18 g of water (16 + 2), both compounds being hot, one can deduced that 210 Gt of hydrocarbons produced about 270 Gt of extra hot water that joined the pool of water already present in 1870. Compared with the water released from 28 million GT of ice lost between 1994 and 2017 [12], the estimated 270 Gt of extra water cumulated since 1870 corresponds to c.a. 1 year of recent ice loss and, thus, is rather small. This water was inserted in the environment and dispatched between biomass, atmosphere, ground, ice and liquid water. The part that ended in the atmosphere may have added extra greenhouse-type heating considering the higher efficiency of water relative to $CO_2$. This possibility has not yet been addressed as far as we know. Anyhow, AHR will become more and more problematic if oil and natural gas consumption continues to grow over the years as is doing the energy production [29-20]. Fighting the sources of $CO_2$ is a solution in the context of surplus of greenhouse effects. However, this policy may appear inadequate if AHR is confirmed in the future as a significant factor in climate changes. Replacing fossil sources of energy by $CO_2$-free sources of energy may decrease the related greenhouse effects as described in the IPCC report, but these alternative sources will continue to produce AHR, in particular if the growing humanity needs, as predictable, more and more energy to satisfy comfort, activities, and more generally economy. Under these conditions, trying to minimize the consequences of anthropogenic $CO_2$ on the climate while keeping the growth of energy consumption, and thus of the anthropogenic heat production and release, may rapidly appear like attempting to square the circle.

## AN ATTRACTIVE POTENTIAL SOLUTION

Any solution will have to satisfy the energy demand with much less production of heat than today. This is going to be essential to slow down ice melt and minimize the amplification of chaotic turbulences. Hydrogen is a potential solution because it can be produced from water and it regenerates water after exploitation as source of energy according to the reaction: energy + $H_2O \rightarrow H_2 + ½ O_2 \rightarrow$ energy + $H_2O$. This chemistry is of particular interest if the energy needed to dissociate water by electrolysis is produced by low heat-producing renewable sources of electricity [21]. However hydrogen is still largely issued from oil-based chemistry. What is presently missing to decide whether a source of energy is better than another relative to AHR is a heat-cycle assessment from cradle to grave, as it is currently done when life-cycle assessment is used to compare processes and materials relative to their impact on the environment [22]. So far, it seems that no information is available regarding the heat-cycle of wind turbines and solar photonic sources of electricity to compare them to the other sources of energy and their relative thermal impact on the climate. Hydro-electricity may be of particular interest in this regard. It should be the task of specialists in thermodynamics working together with climatologists and probably scientists of other disciplines to make such evaluations.

## CONCLUSION

To complete the previous analysis that led to the attribution of the important ice loss observed during 23 years to anthropogenic heat releases, heat management on Earth was compared to that which cools the inner part of a refrigerator. The comparison showed that water acts as a refrigerant to transfer absorbed solar heat, and anthropogenic heat as well, to the upper atmosphere cooled by radiative transfer to space. It was also shown that on Earth, as in a refrigerator, ice helps to control the temperature until it disappears completely. The buffering action of ice melting is complemented by the buffering action of the evaporation-condensation equilibrium on global warming and ocean rise. In addition to their contribution to the formation of anthropogenic heat, this work emphasized that the combustion of hydrocarbon-based sources of energy generates new water on Earth. This newly formed water joins the water present before the exploitation of oil and gas. However, its estimated amount is still minor compared to the water generated by ice loss. Finally, heat-cycle assessment is proposed to compare the different sources of energy and determine which ones may replace those currently exploited while producing less heat and less $CO_2$. Water seems to be an interesting candidate if the derived hydrogen can be produced by electrolysis with competitive heat-cycle and life-cycle assessments in relation to climate and environment, respectively. The comparison relative to other sources of energy on the basis of heat-cycle and life-cycle assessments will have to be done by scientists of different disciplines working cooperatively.

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